June 24, 1947. C. DEPEW ET AL 2,422,659

SPARK GAP DISCHARGE DEVICE

Filed Aug. 21, 1943 2 Sheets-Sheet 1

FIG. 1

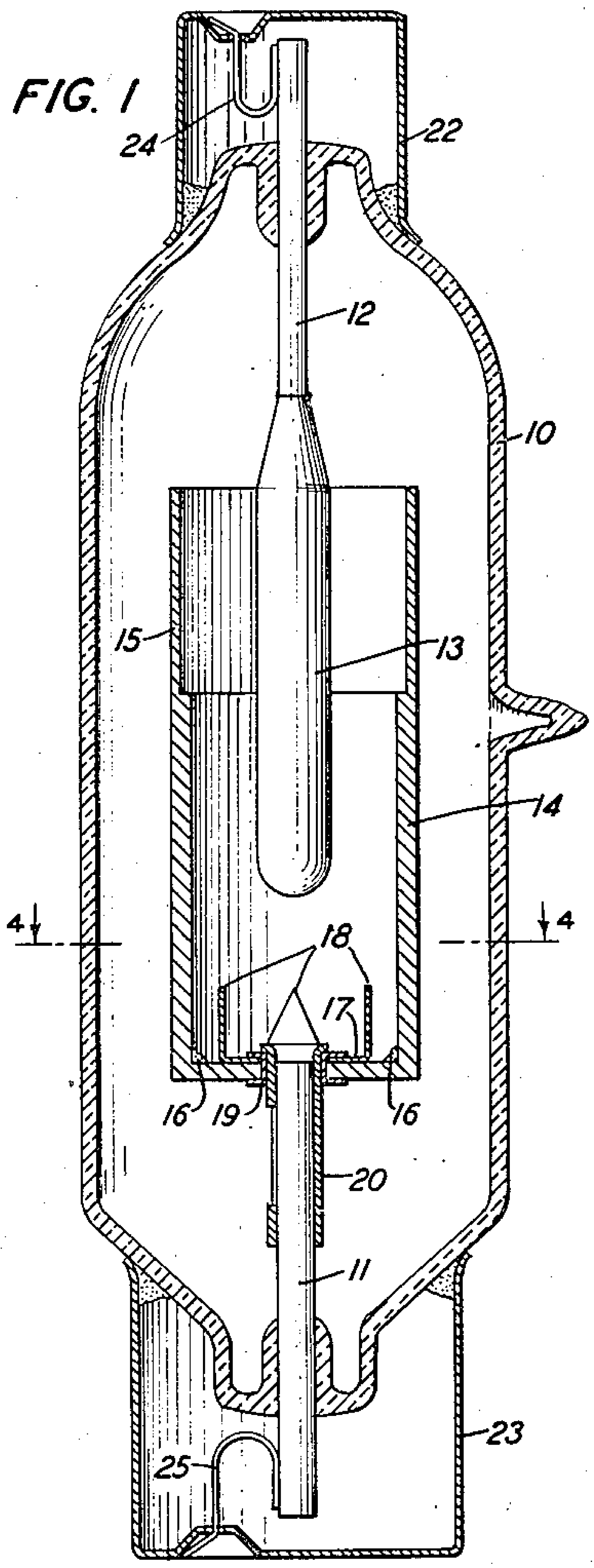


FIG. 2

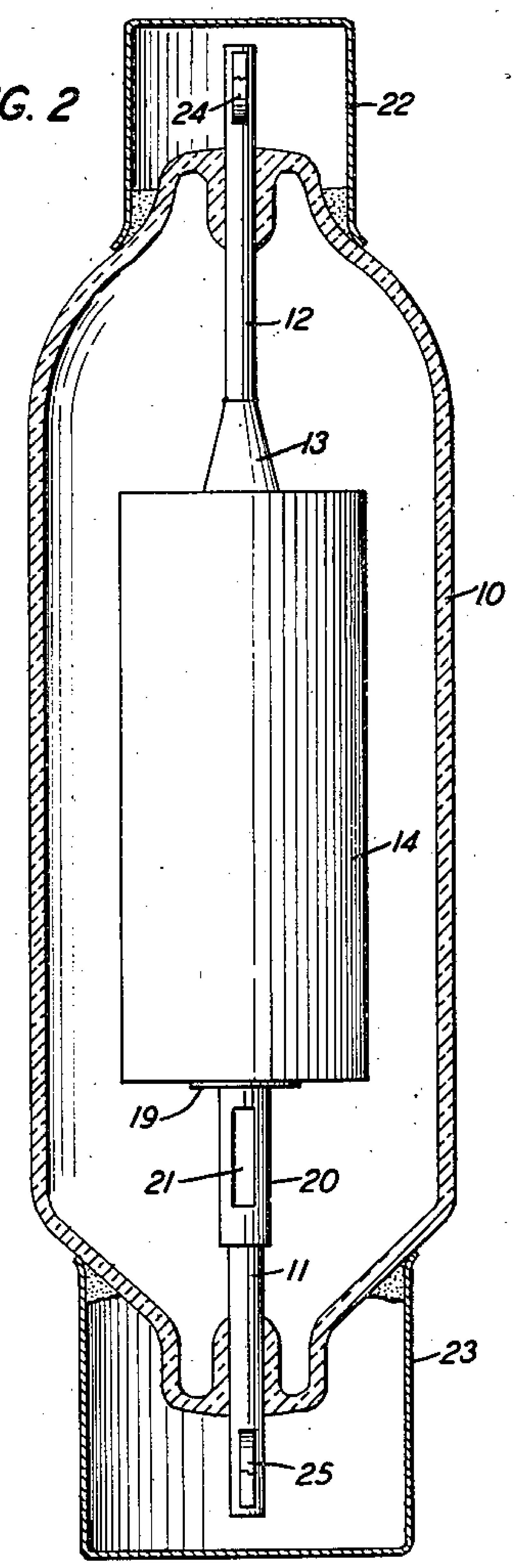


FIG. 3

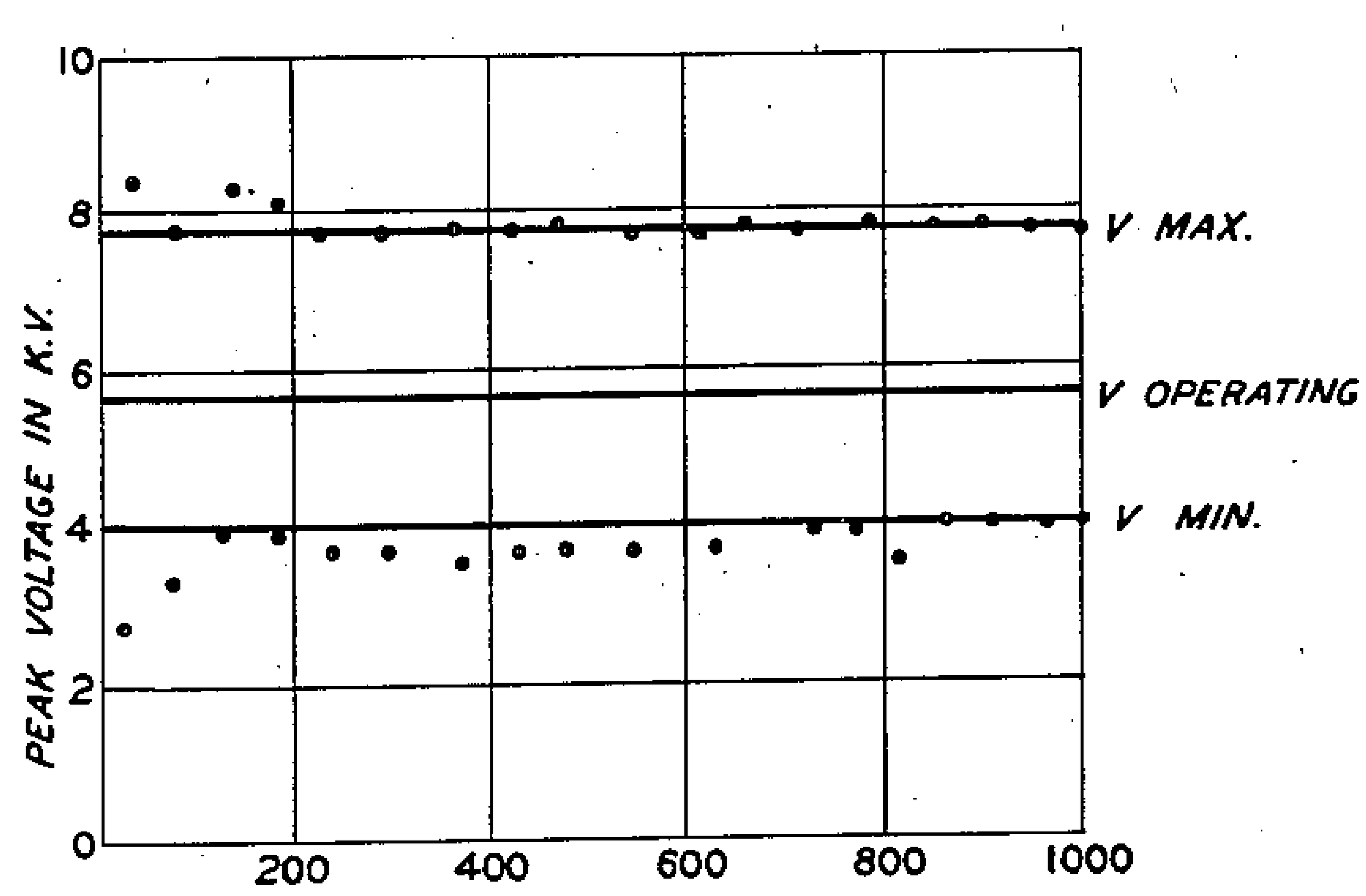
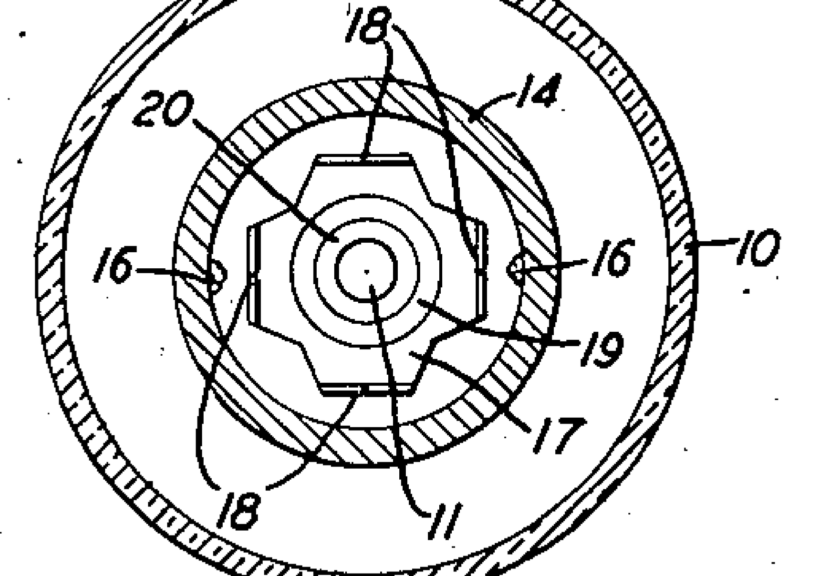


FIG. 4



INVENTORS: C. DEPEW
W. A. DEPP
A. N. LUCE

BY

Walter C. Kiesel

ATTORNEY

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Filed Aug. 21, 1943 2 Sheets-Sheet 2

FIG. 5

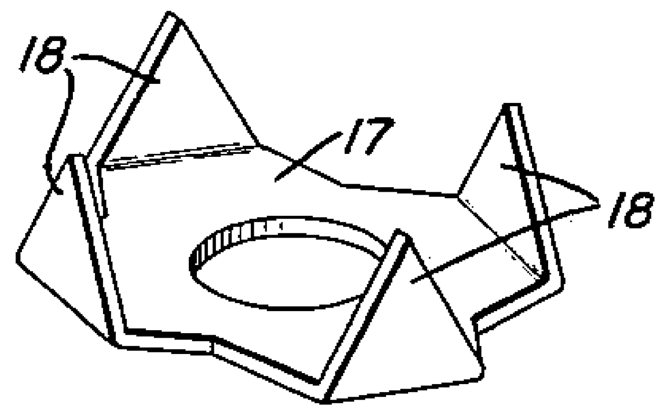


FIG. 6

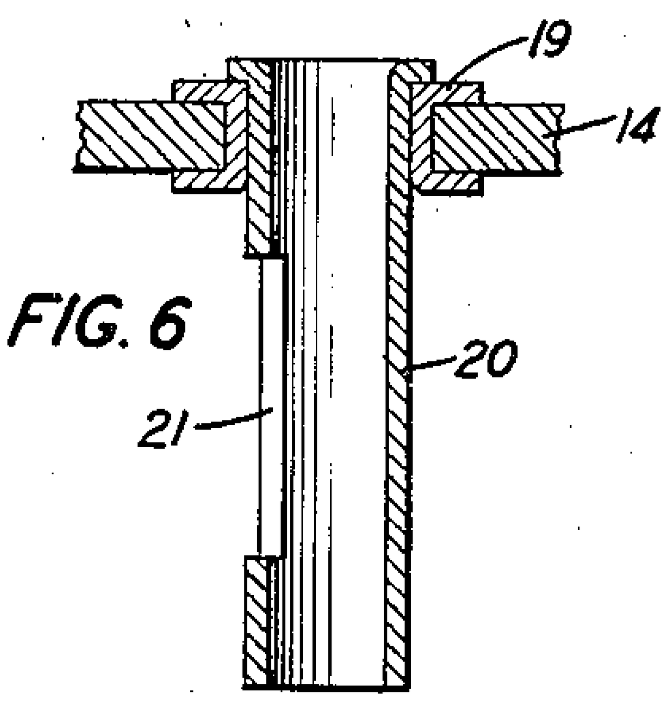


FIG. 7

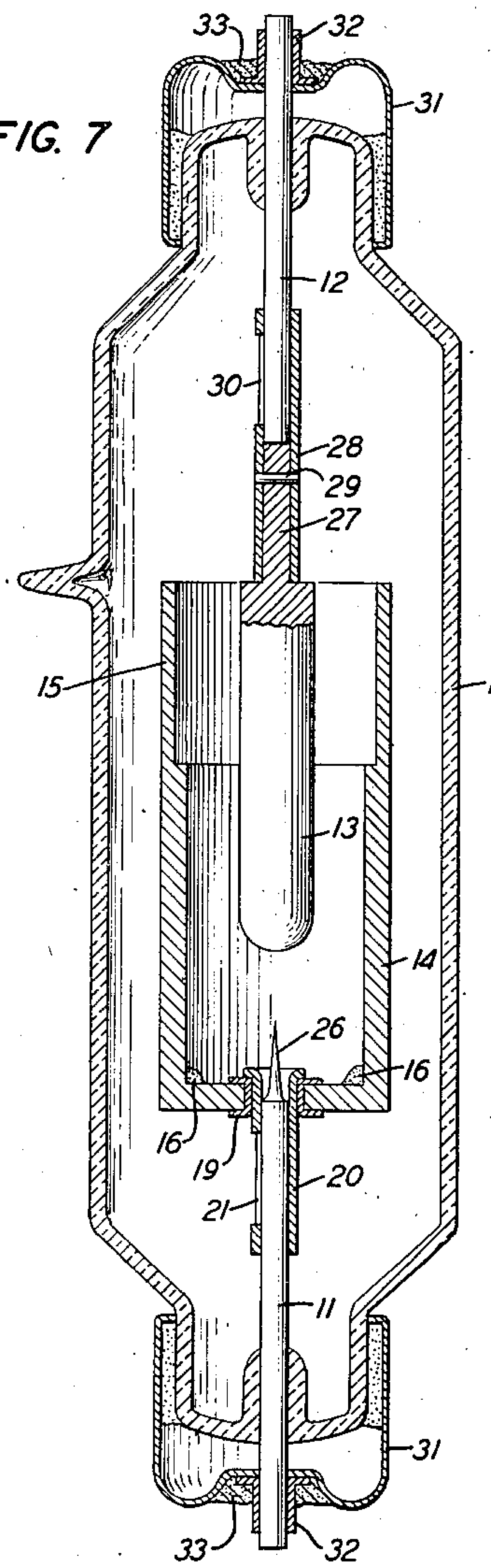
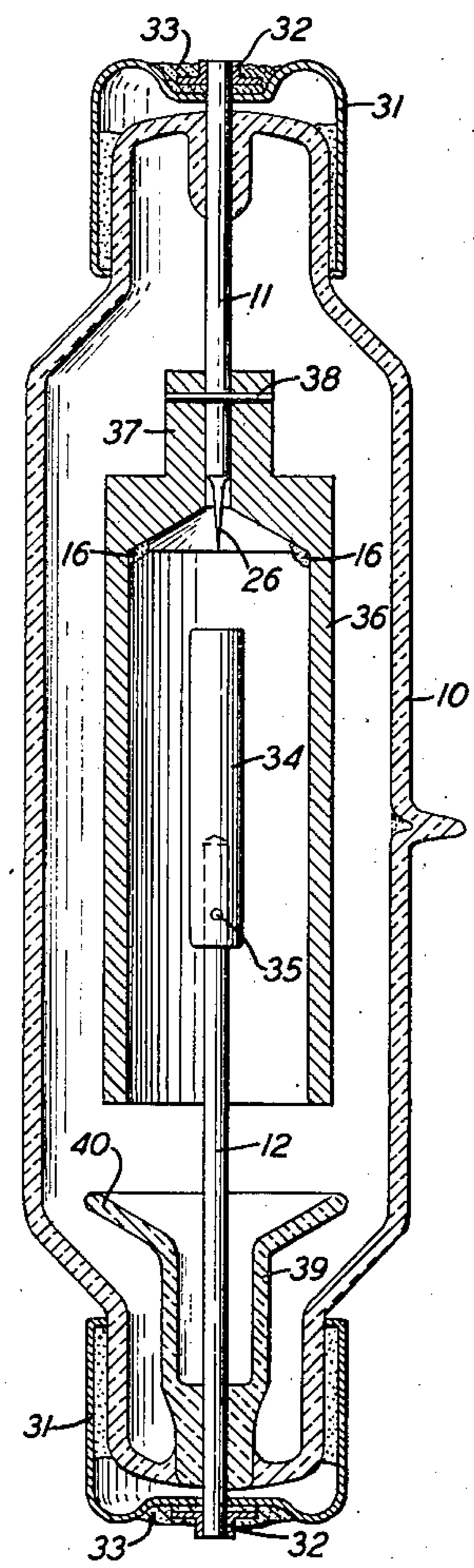


FIG. 8



INVENTORS: C. DEPEW
W. A. DEPP
A. N. LUCE

BY
Walter C. Kiesel
ATTORNEY

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SPARK GAP DISCHARGE DEVICE

Charles Depew, Oakland, N. J., and Wallace A. Depp, Elmhurst, and Alfred N. Luce, Port Washington, N. Y., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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13 Claims. (Cl. 250—27.5)

1

This invention relates to spark gap discharge devices and more particularly to such devices operating in a stable gaseous atmosphere at high pressure for controlling an ionizable discharge within definite limits of breakdown voltage.

The attainment of constant controlling characteristics in a spark gap discharge device and the prolongation of its operating life over a long period, particularly with respect to constancy of its definite breakdown limits especially useful in triggering the device in pulse signaling systems of high voltage and high periodicity, entail many variable factors which render the spark discharge unstable. Some of these factors affect the starting discharge, the operating discharge, the type of discharge, the time lag, electrode sputtering, erosion, deionization, maintenance of uniform spacing between the electrodes and the instantaneous sharp cut-off of the spark discharge to eliminate destructive glow persistence in the discharge.

In order to achieve stable operation over a range substantially between 1 kilovolt and 10 kilovolts, it is essential that the gap between the electrodes should break down so that a low voltage drop exists between the electrodes to prevent a transient high pressure glow occurring to prolong the discharge which results in excessive sputtering of the electrodes and particularly the cathode whereby the uniformity of gap spacing between the electrodes is soon altered thereby resulting in irregular operation and short operating life. Furthermore, after initial breakdown of the spark gap a relatively large current is conducted through the device at a relatively high repetitious rate, for instance, of the order of 1,000 pulses per second and such characteristics can be maintained over a relatively long operating life.

An object of the invention is to insure stable operation of the discharge gap in a unidirectional path which is substantially confined by one of the electrodes.

Another object of the invention is to facilitate the breakdown of the gap within a wide range of voltages over which triggered operation is obtained.

A further object of the invention is to initiate conduction between solid electrodes in a gas-filled vessel at a low triggering voltage.

Another object of the invention is to increase the efficiency of the discharge gap between the electrodes by the provision of initiative components in the enclosure within the confines of the gap.

A further object of the invention is to increase

2

the stability of the discharge gap in a controlled atmosphere by the incorporation of multiple corona points in the gap.

Still another object of the invention is to facilitate the operation of the device over a long period without material alteration of the space relation of the electrodes in the gap due to the sputtering of cathode material.

In accordance with this invention the spark gap discharge device comprises a gas-filled receptacle of the cartridge type having terminals at opposite ends which are joined to oppositely disposed central conductors sealed in the receptacle. A cylindrical anode rod is attached to one of the conductors and extends axially within the receptacle and a cup-shaped cathode is carried by the other conductor and is uniformly spaced from the sides and end of the anode rod which it surrounds.

The cathode is rigidly affixed to the conductor by an intermediate sleeve member mechanically and electrically joined to the cathode and secured to the conductor. In another form of the device the anode may be affixed to its respective conductor in a similar manner. The receptacle is provided with a gaseous filling, such as hydrogen, at a pressure extending over a range from one-half to several atmospheres, depending on the range of voltages applicable to the device, to stabilize the spark discharge and also facilitate the constancy of the operation of the device with high efficiency over a long life. The enclosed cathode structure materially enhances the uniformity of the spark discharge by decreasing the sputtering effect produced in the gap. The cathode is also provided with a shielding skirt portion which surrounds the anode termination to prevent the discharge being lengthened to the exterior surface of the cathode, and to materially decrease the deposition of sputtered material from the cathode onto the wall of the receptacle.

Another feature of this construction is the inclusion of multiple corona points within the confines of the cathode to insure constant firing of the discharge gap at the instant of maximum potential whereby ultra-violet radiation from the corona reduces the time lag in the initiation of the discharge breakdown between the cathode and anode. This is accomplished by the provision of a star-shaped member enclosed in the cathode and closely associated with the discarge path so that the array of points facilitates the primary sparking of the gap. This arrangement materially increases the accurate breakdown of the discharge gap with minimum time lag.

A further feature of the invention relates to the termination of the spark discharge immediately after breakdown of the gap to prevent the establishment of a transient high pressure glow discharge having a high cathode fall of potential. The glow discharge is eliminated by the addition of an inert gas, such as argon, together with the hydrogen filling in the proportions of approximately 25 per cent argon and 75 percent hydrogen.

A further feature of the invention relates to the coupling of the terminal contacts of the cartridge vessel to the conductors in the device to compensate for temperature changes due to the high potentials incident to the operation of the discharge gap. This arrangement utilizes a flexible coupling between the conductors and the terminals of the device to neutralize excessive temperature variations between the conductors and the caps to overcome leakage or fracture of the seals which might endanger the use of the device by leakage of oxygen into the gaseous filling causing damage or explosion of the device.

These and other features and advantages will be more clearly set forth in the following detailed description which, together with the accompanying drawings, embodies a complete disclosure of this invention.

Fig. 1 illustrates in an elevational cross-sectional view, the embodiment of this invention of a high breakdown voltage spark gap discharge device;

Fig. 2 is the same view of the device of Fig. 1 with the coaxial electrodes shown in full view and the device turned 90 degrees to illustrate the coupling of the cathode to its conductor;

Fig. 3 is a graphic plot of the maximum and minimum voltage limits and the operating characteristic of the device intermediate these limits to insure safe margins for the control characteristics of the device;

Fig. 4 is a plan view of Fig. 1 taken on the line 4—4;

Fig. 5 is an enlarged perspective view of the multiple corona point element enclosed within the cathode as shown in Fig. 1;

Fig. 6 shows an enlarged fragmentary view in cross-section of the coupling connection of the cathode and its supporting sleeve;

Fig. 7 is a view in cross-section of a modified form of the invention in which both electrodes are of like metal and a single corona point is located within the cathode; and

Fig. 8 illustrates another modification in cross-section showing details of assembly and a dielectric shield embracing the anode conductor adjacent the seal.

Referring to the drawing, and particularly to Figs. 1 and 2, a high voltage spark gap discharge device of this invention capable of conducting high currents, of the order of 200 amperes, embodies a cylindrical cartridge type vessel or receptacle 10 having tungsten conductors 11 and 12 sealed in opposite ends and extending within the vessel along the axis thereof. A solid nickel rod 13 extends along the axis of the device and is provided with a rounded or dome end while the opposite end is tapered and welded to conductor 12 extending from one end of the vessel. The nickel rod which functions as the anode of the device, in a particular embodiment is formed of a rod of 3/16 inch diameter and is substantially wholly enclosed by a cylindrical cup-shaped aluminum cathode 14 which is coaxially mounted about the anode 13, the cathode having a thick wall portion adjacent the free end of the anode and a depending skirt portion 15 of one-half the thickness of the main wall portion surrounding the terminal end of the anode with the space relation between the internal wall of the cathode and the lateral surface of the anode being approximately 150 mils or .150 inch. The main discharge occurs across the gap between the heavy wall portion of the cathode and the end of the anode which it surrounds, while the skirt portion 15 of the cathode materially reduces the escape of any sputtered material to the wall of the vessel. The cathode is preferably formed of aluminum to reduce the sputtering rate in the high voltage spark discharge gap and the improved construction materially limits the spark discharge to the active surfaces of the electrodes where it is wholly confined.

In order to initiate ionization between the electrodes to effect breakdown of the gap therebetween, a material 16 is deposited within the cathode enclosure to effect the presence of free ions in the discharge gap. This material may be radium bromide or chloride which is painted on the cathode surface in the form of small spots to introduce the desired amount of ion producing substance therein which is approximately 2 micrograms. In addition, the breakdown discharge in the gap is initiated with a minimum of time lag by a multipoint element, as shown in Fig. 5, which is formed of a steel plate 17 of star shape having the points 18 bent at right angles to the plane of the base of the plate to provide a multiplicity of corona discharge points for the initiation of the breakdown of the discharge to the rounded end of the anode 13, the multicorona point element being positioned coaxially on the end wall of the cathode 14 and wholly enclosed in the discharge gap within the immediate firing area of the discharge, the points being equally distributed about the end of the anode approximately at a distance of 3/16 of an inch. The corona point element is rigidly affixed to the cathode by an eyelet 19 and the assembled construction is secured to the conductor 11 by a steel coupling sleeve 20, by welding the spun end of the sleeve to the eyelet and the slotted shank 21 to the conductor 11. The vessel is filled with a gaseous mixture of hydrogen 75 per cent and argon 25 per cent at a pressure from 45 to 67 centimeters of mercury or approximately two-thirds atmospheric pressure, the hydrogen being purified by passing it over palladiumized asbestos to remove oxygen. A terminal cap 22 is cemented to one end of the vessel through which conductor 12 extends for the anode and a larger diameter terminal cap 23 is cemented to the other end of the vessel through which extends the cathode conductor 11 to polarize the device and insure the correct insertion of the device in a mounting. These terminal caps are attached to the respective conductors by flexible straps 24 and 25, respectively, to compensate for temperature changes in the expansion and contraction of the conductors under the high temperature and high current operation of the device to protect the hermetic seals of the conductors in the device.

The correlation of the various components entering into the construction of the improved spark gap trigger device of this invention results in securing the most efficient operation and a relatively long operating life despite the high currents encountered in the intensive character of the discharge. Furthermore, the extent of the controlling range is substantially constant throughout the continued operation of the device. This is attributable to the distribution of the discharge in a rotating direction over the inner surface of the cathode and the symmetry of the electrodes, their physical character and the facility with which the device breaks down under the controlling potentials substantially uniformly with constant characteristics. The distribution of the discharge also prolongs the life of the device since sputtering of cathode material is more uniform over the discharge surface of the cathode so that concentrated deposit on the anode is avoided.

The conditions of operation of the device may be realized from a perusal of the time vs. voltage diagram shown in Fig. 3, in which hours of operation are plotted as ordinates and the voltage range as abscissae. The working range for a typical device is shown in the form of solid dots varying but slightly with time where at slightly below 8,000 volts the maximum voltage or V_{max} is represented as the upper limiting voltage of the device over which the spark discharge changes to a continuous arc discharge. The lower limit of the device is in the 3,000 to 4,000 volt range below which the device fails to spark without interruption. Selecting a medial point between these limits represents a safe operating potential or V operating characteristic which insures an adequate margin above and below the operating voltage so that the device may be operated within the range represented by the upper and lower dots at a definite time interval.

The static spark gap device, as shown in Fig. 1, is usually operated in pairs or three in series with unlike electrodes connected together for switching pulsing circuits of high periodicity, three or more units being employed for exceedingly high voltages while two units are commonly employed for a voltage range from 3 to 8 kilovolts, the controlling voltage being applied to the common point of the pair of units to trigger the gaps substantially simultaneously.

The presence of the radium bromide 16 in the cathode enclosure insures adequate free ions in the firing gap to initiate the discharge when the breakdown potential is applied and the multicorona points 18 equally distributed from the end of the anode 13 facilitate the instantaneous ionization of the gap with a minimum time lag to fire the gap at a minimum sparking voltage.

The high periodicity of the spark discharge in pulsing circuits and the high potentials employed in operation necessarily increase sputtering of material from the cathode but due to the symmetry of the electrodes the material is deposited on the anode surface and, consequently, the gap space relation between these electrodes remains essentially constant thereby insuring uniformity in the characteristics of the discharge. Furthermore, the aluminum cathode 14 decreases the sputtering rate so that a relatively long operating life is assured. The shielding portion or skirt 15 of the cathode also enhances the continued operation of the device, since the length of the cathode is sufficiently greater than the spark length so that the discharge does not escape from the concentrated path adjacent the dome end of the anode. Similarly, the skirt portion protects the wall of the vessel 10 from sputtered material emanating from the cathode thereby increasing the insulation resistance between the terminal portions of the respective electrodes. The preservation of the high dielectric properties of the vessel is a decided advantage in the high voltage operation of the device,

since the breakdown voltage can be divided equally to the units in series to effect simultaneous triggering of the gaps and avoid preferential arcing in one device which would occur if leakage paths were formed between the terminals of the electrodes.

A modification of the invention is disclosed in Fig. 7 in which the electrodes are formed of similar materials and the starting discharge is considerably reduced by the incorporation of a single corona point wholly enclosed in the firing path of the discharge. In this construction the cathode conductor 11 is provided with a sharpened point 26 which extends within the cathode 14 and is directly opposite the dome end of the anode enclosed within the cathode. The anode 13 in the device shown in Fig. 7 is slightly different in construction from the anode described in Fig. 1, since this anode is formed of aluminum and is, therefore, of the same material as the cathode 14, the aluminum rod being provided with a shank portion 27 exterior to the cathode and being aligned with the conductor 12 by a coupling sleeve 28 which is secured to the shank by a pin 29 and welded to the conductor 12 along the slot 30 therein. In this construction both electrodes are mechanically and electrically connected to the conductors by coupling sleeves to securely fasten the aluminum electrodes to the tungsten leading-in conductors of the device. Another change in the construction of the device, as shown in Fig. 7, is the connection of the conductors in the vessel to the terminal caps on the ends thereof. Each cap 31 is cemented to a reduced portion of the enclosing vessel adjacent the leading-in conductor and is provided with a central depressed portion through which the conductors 11 or 12 extend. A flanged sleeve 32 is welded to the conductor exterior to the shell or terminal and the flange portion is embedded in a fusible metal mass 33, such as solder, to provide a flexible connection in the cap to compensate for expansion and contraction in the seal of the conductor entering the vessel.

A further modification of the invention is shown in Fig. 8 in which an anode rod 34 of nickel or aluminum is counterbored to receive the end of the conductor 12 extending into the vessel, the anode being secured to the conductor by a transverse pin 35. The cathode 36, preferably formed of aluminum, has an elongated wall completely surrounding the anode 34 and is provided with a cylindrical bored extension 37 through which the sharpened corona point conductor 11 extends, the cathode being rigidly secured to the conductor by a transverse pin 38. In this construction a dielectric flanged cup shield 39, formed preferably of glass, is sealed to the conductor 12 and also to the vessel 10 with the flanged portion 40 projecting toward the open end of the cathode so that any sputtered material escaping from the discharge path between the electrodes will be deposited on the surface of the shield and, therefore, will not endanger the insulation path along the inner wall of the vessel between the oppositely disposed conductors 11 and 12 of the electrodes.

While various modifications and structural assemblies of the devices of this invention have been disclosed, it is, of course, understood that other mechanical changes can be incorporated in the structural features of the device of this invention without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. An ionic pulsing relay having high breakdown periodicity characteristics comprising a vessel containing a gaseous filling substantially at pressures from one-half to several atmospheres, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors, and an elongated cathode surface concentrically surrounding said anode across a short gap and supported by the other conductor, the radial distance between the inner cathode wall and the lateral surface of said anode being uniform to distribute the striking of the discharge over an annular path, said cathode having a depending cylindrical portion surrounding the terminal portion of said anode at a greater distance than the striking discharge path to prevent the extension of the spark discharge to the wall of said vessel.

2. An ionic relay comprising a cartridge type vessel containing a gaseous filling substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a cylindrical anode rod of solid nickel carried by one of said conductors, an elongated cup-shaped aluminum cathode coaxially surrounding said anode across a short gap and supported by the other conductor, and multiple corona points equally disposed opposite the end of said anode and supported by said cathode.

3. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors, an elongated cup-shaped cathode concentrically surrounding said anode across a short gap and supported by the other conductor, a corona point element supported in the base of said cathode and disposed opposite the end of said anode, terminal caps on opposite ends of said vessel surrounding said conductors, and flexible connections between said conductors and said terminal caps.

4. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors, an elongated cup-shaped cathode concentrically surrounding said anode across a short gap and supported by the other conductor, multiple corona points equally disposed opposite the end of said anode and supported in the base of said cathode, a cup-shaped terminal on one end of said vessel for said anode, a larger diameter cup-shaped terminal on the other end of said vessel for said cathode, and resilient metallic connectors extending between said terminals and the conductors for said cathode and anode.

5. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors, an elongated tubular cathode concentrically surrounding said anode across a short gap and supported by the other conductor, and a star-shaped metallic member having the points bent at an angle secured to the innermost end of said cathode, said points being directed towards said anode.

6. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling of hydrogen and argon substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors, an elongated tubular aluminum cathode concentrically surrounding said anode across a short gap and supported by the other conductor, and a multipoint metallic member secured to the wall of said cathode opposite the active end of said anode, the points thereof extending parallel to the side wall of said cathode and spaced in equal distribution from the active end of said anode.

7. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling of hydrogen and argon substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors and extending axially along said vessel, an elongated cylindrical aluminum cathode concentrically surrounding said anode across a short gap and supported by the other conductor, a corona point element wholly enclosed in said cathode and directed toward the end of said anode, and a coupling sleeve attached to said cathode, element and said conductor.

8. An ionic trigger device comprising a cartridge type vessel containing a gaseous filling of hydrogen and argon substantially at atmospheric pressure, individual conductors sealed in each end of said vessel and extending along the axis thereof, a rod-shaped anode carried by one of said conductors and extending along the axis of said vessel, an elongated tubular aluminum cathode concentrically surrounding said anode across a short gap and supported by the other conductor, a corona point element wholly enclosed in said cathode and directed toward the end of said anode, an eyelet clamping said member to the inner surface of said cathode, and a slotted sleeve welded to said eyelet and said conductor.

9. An ionic trigger device comprising a cartridge type vessel containing a gaseous mixture substantially at atmospheric pressure, a pair of lead-in wires sealed in opposite ends of said vessel, a central electrode, and a hollow concentric electrode enclosing said central electrode, one of said wires having a sharp point extending axially of and within said hollow electrode and shielded thereby, and metallic sleeve members rigidly coupled to said lead-in wires and said electrodes respectively.

10. A high voltage spark gap trigger device comprising a cartridge type vessel containing an ionizing mixture of hydrogen and argon at a pressure from 45 to 67 centimeters of mercury, central conductors extending into opposite ends of said vessel, a cylindrical cup-shaped cathode supported co-axially in said vessel, a cylindrical rod-shaped anode extending axially within said cathode and connected to the other conductor, means to initiate ionization in said mixture, means positioned in the base of said cup-shaped cathode for facilitating a corona discharge in said gap between said cathode and anode, and a cup-shaped shield member on said conductor supporting said anode and extending toward said cathode.

11. A high voltage spark gap trigger device comprising a cartridge type vessel containing an ionizing mixture of hydrogen and argon at a pressure of 45 centimeters of mercury, central

conductors extending into opposite ends of said vessel, a cylindrical cup-shaped cathode supported coaxially in said vessel, a cylindrical rod-shaped anode extending axially within said cathode and connected to the other conductor, means to initiate ionization in said mixture, means positioned in the base of said cup-shaped cathode for facilitating a corona discharge in the gap between said cathode and anode, and terminal caps attached to opposite ends of said vessel, said conductors extending therethrough and being soldered to said cap.

12. A high voltage spark gap trigger device comprising a cartridge type vessel containing an ionizing mixture of hydrogen and argon at a pressure of 45 centimeters of mercury, central conductors extending into opposite ends of said vessel, a cylindrical cup-shaped cathode supported coaxially in said vessel and attached to one of said conductors, a cylindrical rod-shaped anode extending axially within said cathode and connected to the other conductor, means to initiate ionization in said gaseous mixture, and said conductor supporting said cathode having a sharp point extending within said cathode body and spaced directly opposite said anode.

13. A high voltage spark gap trigger device comprising a cartridge type enclosing vessel, an ionizable gaseous mixture therein composed of 75 per cent hydrogen and 25 per cent argon at a pressure of 45 centimeters of mercury, oppositely disposed tungsten conductors sealed in the ends of said vessel and extending along the axis thereof, an aluminum shell type cathode having different wall thicknesses along its length, said cathode having an apertured end portion surrounding one of said conductors, a star-shaped plate having upturned points abutting against said apertured end portion of said cathode, a solid nickel anode rod extending within said cathode shell an supported coaxially therein by said other conductor, the diameter of said anode rod and the space relation of said upturned points from the end of said anode being substantially of the order of $\frac{3}{16}$ of an inch and the radial spacing of said cathode wall from the lateral surface of said anode being approximately $\frac{1}{8}$ of an inch, a metallic eyelet securing said plate to said cathode, and a tubular steel coupling intermediate said cathode and said conductor rigidly affixed to said eyelet and said conductor.

CHARLES DEPEW.
WALLACE A. DEPP.
ALFRED N. LUCE.

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